

Final Report

Stream assessment in the Virginia Coastal Zone: development of a significant new database and interactive assessment application



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The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies.



Objectives

The primary objectives of this study were to: 1.) develop a statistically valid, multivariate model of reference stream conditions for the Virginia Coastal Zone (i.e., a *virtual* reference stream) using a wide range of biological, ecological, and geomorphological variables and 2.) create version 1.0 of an **interactive stream assessment resource** (INSTAR), using ESRI's ArcIMS Internet database and GIS technology.

Methods

Study Areas

Streams within 63 hydrologic units (HUCs) of the Virginia coastal zone were sampled for this study. Specific study sites were randomly selected (i.e., probabilistic sampling) for each HUC using ArcView GIS (©ESRI) software in a two-stage process. First computer-generated points were placed randomly on stream segments corresponding to the mid-point of a 100-m stream segment. Twice the number of candidate sites required was selected in the event some sites were inaccessible and needed to be replaced. The second stage of the selection process included the generation of a random numbers list and subsequent selection of sites corresponding to the numbers. Final site selection was made following a site visit to determine accessibility of the site, obtain landowner permission, and acquire initial habitat notes. Quantitative and qualitative data collected included hydrogeomorphic measurements (Rosgen-like protocols), physical habitat characterization (EPA Rapid Habitat Assessment protocols), fish community data (discussed below), and aquatic macroinvertebrate community data (Rapid Bioassessment Protocol III, discussed below).

Historical data collected by VCU and VDGIF personnel were selected from existing databases for the target HUCs and watersheds. Most archival data available consisted of fish and habitat data. Additional macroinvertebrate data were available from Fairfax County biologists and VCU archives. Selected study areas required Rosgen-type hydrogeomorphic analysis.

Stream classification and instream habitat characterization were conducted using standard protocols: Rosgen (1996) and EPA's rapid habitat assessment (Barbour et al. 1999), respectively. Selected 'Rosgen-like' metrics included: channel gradient, bank-full depth and width, entrenchment ratio (bankfull maximum depth/floodprone area width), and stream width/depth ratio.

The fish community was examined using standard backpack electrofishing protocols for coastal habitats (McIninch and Garman 1999; Smock and Garman 2001). Because chosen study sites were wadable only backpack electrofishing units were required for complete characterization of the fish community. Fishes were stunned working in an upstream direction for the entire 100-meter length of the study site. All fish were collected and placed into a livewell. When the 100-m mark was reached electrofishing was ceased and effort (in seconds of electrofishing) recorded. Fishes were individually examined for physical anomalies, identified, enumerated and released.

The aquatic invertebrates were collected using D-frame dip-nets and protocols modified from Rapid Bioassessment Protocols (Barbour et al. 1997; Maxted et al. 1998). Dip nets were used to jab in various habitat types for the collection of invertebrates. Habitat types included wood (large or accumulation of smaller woody debris), bank margins (including root masses associated with undercut banks), and leaf litter accumulations or submerged macrophytes. Habitats were sampled in proportion to their abundance within the entire 100 m sampling site. Samples were preserved in alcohol dosed with Rose Bengal stain and returned to VCU for subsampling, sorting, and taxonomic identification. A subsample of 200 organisms was selected as the sample abundance. Organisms were identified to the lowest practicable taxonomic level, which was species for most groups.

Metrics

Habitat/ Physical Data

The quality of habitat for each study site was determined by visual assessment (Barbour et al. 1999; Barbour and Stribling 1991). A total of nine habitat parameters was used to score each site (Table 1): instream habitat availability, pool depth and variety, channel alteration, sediment deposition, channel flow, bank stability and vegetation characteristics, and condition of the riparian zone. Each metric was rated using a numerical scoring system where 0 is the poorest condition and 20 points is awarded for the best (or optimal) condition. For bank vegetation and riparian zone metrics, each bank was rated separately (0-10 points) and aggregated to provide one score for the metric.

Table 1. Physical habitat parameters assessed/measured.

Habitat assessment

1. Amount of epifaunal substrate or available cover for aquatic organisms
2. Characterization of substrates associated with pool habitat
3. Variation of pool types within the study site
4. The extent of alteration, if any, to the stream channel
5. Extent of sediment deposition throughout the study site
6. Extent of water flow in the channel
7. Type and degree of bank vegetation
8. Stability of bank sediments
9. Width of the vegetated riparian zone

Rosgen stream classification

1. Percent slope of stream throughout study site
2. Sinuosity of stream (channel length over valley length)
3. Entrenchment ratio (width of floodprone area to width at bankfull height)
4. Ratio of stream width to depth

Fish and Macroinvertebrate Data

Twelve fish metrics were used to assess the fish community at every site. These metrics complement those of the Index of Biotic Integrity (IBI) originally developed by Karr (1981) for Midwestern streams and modified for use in Virginia's coastal area by the authors (McIninch and Garman 1999). The IBI design is intended to assess the fish community through three groups of metrics corresponding to diversity and abundance of the fishes, functional composition and overall health of the fish community. The twelve metrics used for this pilot study and a brief description of their measurement is presented as Table 2. A subset of these metrics was used to develop a modified Index of Biotic Integrity (mIBI), which is used by INSTAR to conduct broad-scale, HUC-level stream assessments.

Table 2. Fish Community Metrics

Metric 1 -- Species Richness.

Total number of **native** species in the sample, not including hybrids. Because of their long freshwater resident status (up to 20 year; Jenkins and Burkhead 1994), American eels are considered resident species. Introduced species are considered elsewhere (Metric 11).

Metric 2 -- Total Number of Individuals

The total number of individuals in the sample, expressed as catch per unit effort (CPUE), where effort is backpack electrofishing time (minutes).

Metric 3 -- Total Number of Darter Species

The total number of darter (*Etheostoma* and *Percina* spp.) species per sample. A total number of 6 species is possible.

Metric 4 -- Total Number of Sunfish Species

The total number of members of the Centrarchidae family, black basses included.

Metric 5 -- Total Number of Sucker Species

The total number of sucker species (family Catostomidae) in the sample;

Metric 6 -- Intolerant Species

The total number of species, per sample, classified as "intolerant" of degraded stream conditions. Intolerant species will include northern hogsucker, rosyside dace, stripeback darter, shield darter, and least brook lamprey.

Table 2., cont.

Metric 7 -- Tolerant Species The percentage of individuals classified as “tolerant” of degraded stream conditions. This metric will use the relative abundance of a guild of species to replace the “green sunfish” metric of Karr (1981), as suggested by Karr et al. (1986). Tolerant species will include creek chubsucker, American eel, golden shiner, pumpkinseed, bluegill, common carp, goldfish, brown bullhead, eastern mudminnow and tessellated darter.

Metric 8 -- Omnivorous species

The percentage of individuals per sample classified as omnivores; species will include: creek chubsucker, goldfish, common carp, chubs of the genus *Nocomis*, spottail shiner, brown bullhead, white sucker, white catfish and channel catfish.

Metric 9 -- Insectivorous cyprinids

The percentage of cyprinid individuals per sample classified as insectivores; species will include satinfish shiner, swallowtail shiner, common shiner, comely shiner, rosyside dace, rosyface shiner, and blacknose dace.

Metric 10 -- Piscivores

The percentage of individuals per sample classified as facultative piscivores (apex predators), species will include: bowfin, longnose gar, chain pickerel, largemouth bass, black crappie, and blue catfish

Metric 11 -- Introduced species

The percentage of individuals per sample classified as non-indigenous species. This metric replaces the “hybrid” metric of Karr (1981) because hybrid identifications are often problematic especially in the field. Moreover, the numerical dominance of exotic taxa in disturbed ecosystems is well documented in the literature. Both the new “introduced” metric and the “hybrid” metric (Karr 1981) influence the overall IBI score most significantly under poor and fair stream conditions.

Metric 12 -- Anomalies

The percentage of individuals per sample exhibiting external parasites, infections, deformities, or skeletal anomalies. Minor blackspot found on individuals was not considered an anomaly.

Similar metrics assessing macroinvertebrate communities were also used at each study site. The seven metrics calculated have been determined as being the most appropriate to use in the coastal area (Smock and Garman 2000). The metrics used included richness measures, composition measures, tolerance measures, and habitat measures (Table 3).

Table 3. Rapid Bioassessment Protocol III Metrics used for Macroinvertebrate assessment. Scoring follows Smock and Garman (2001).

Metric 1 – Taxa Richness

The total number of taxa identified

Metric 2 – Modified Hilsenhoff Biotic Index (HBI)

$$HBI = \sum (X_i t_i / n)$$

where X_i = number of individuals of taxon i in a sample;

t_i = tolerance value of taxon i ;

n = total number of organisms in the sample

The HBI offers a quantitative assessment of the tolerance of each taxon to general water quality degradation. Tolerance values have been derived from Lenat (1993) and Pflakin et al. (1989). Values for rare species without published values were estimated based on experience of macroinvertebrate team.

Metric 3 – Scraper ratio

This is the direct ratio of the number of individuals in the scraper functional feeding group to those in the collector or filterer feeding groups.

Metric 4 – EPT ratio

This is the direct ratio of the individuals in insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies) to the number of individuals in the dipteran family of Chironomidae.

Metric 5 – Percent dominant taxa

The percent contribution of the dominant taxon in the sample as the number of individuals of the most abundant taxon divided by the total number of individuals.

Metric 6 – EPT index

The number of individuals in the three orders listed above (EPT) divided by the total number of individuals.

Metric 7 – Percent shredder taxa.

The number of individuals in the shredder functional feeding group divided by the total number of individuals.

Statistical Analyses

Data was assembled into a single database for analysis. We used Microsoft Excel, dBase 5.0, and the FORTRAN based CANOCO program. All raw data was initially examined through quality assurance procedures for data entry errors, outliers and those variables exhibiting no variation. Appropriate corrections and transformations were made to the data prior to further analysis. We initially used ASSESS Version 3.0 to compile index of biotic integrity scores for fish data and Rapid Bioassessment index scores for macroinvertebrate data. Following development of INSTAR databases, macros within INSTAR were used for IBI and RBP assessments. Correspondence analysis (CA) and detrended correspondence analysis (DCA) were used to arrange (ordinate) the study sites along axes based on the physical and biological data collected. The objective of ordination is to arrange the points such that points that are close together correspond to sites that are similar in those attributes examined (biological and/or physical data). Those sites most similar with respect to their biological communities and abiotic attributes would, therefore cluster together and be distant from dissimilar sites.

Due to the large geographic area sampled for this study we first examined the entire dataset for variation due to inherent differences in communities among drainages. Due in part to the large amount of variation within the large dataset, it was determined that interdrainage differences did not warrant separate drainage analyses. The initial set of ordination analyses allowed for the reduction in number of variables by eliminating those variables that did not significantly contribute to the separation, or clustering, of sites. The elimination of certain variables is not an indication of their importance to the structure or function of the ecosystem rather that the variability among all those sites examined was not strong enough to aid in the separation among sites. The initial CA was performed on the fish, macroinvertebrate, and physical data separately. Because of the large number of collections sites, species and variables in general, the arch effect was present in many of the initial procedures. If the arch effect was noted from initial analyses (i.e. if sample scores on the second axis approximate a quadratic function of the scores on the first axes), then detrended correspondence analysis (DCA) was performed using a 2nd order polynomial detrending to remove this effect (Jongman et al. 1987; Ter Braak 1988). Once the insignificant variables were removed, remaining variables were lumped into a single file and analyzed again using DCA. The final direct gradient analysis was a canonical correspondence analysis where both biological and physical data are present. Again, the results are a graphical representation of the relations among sites based on the variables of interest. The gradients of the figure (graphical representation; left to right and top to bottom) are representations of how strong any given variable separates or clusters the sites. Further explanation will be presented in the results section.

We assumed that there was an underlying (or latent) structure in the data, i.e. that the occurrences of the biological communities and characteristics of the physical data are determined by some unknown set of parameters that may reflect impacts associated with physiographic differences, site specific differences in anthropogenic impacts, variable habitat quality, etc. In order to examine the response of our data to a simple model we performed multiple linear regression analyses (stepwise procedure, SPSS®) with selected variables from the previous analyses shown to be the strongest correlated with study site ordination. Variables that did not meet statistical assumptions (e.g. normality) were transformed as appropriate. All percentage data were arcsine transformed. The site scores (i.e. coefficients from the final DCCA) were entered as the response variable and significant biotic and abiotic variables entered as explanatory variables. Those statistically significant ($P > 0.05$) were used to develop the initial virtual' stream model (Figure 1).

RESULTS

Approximately 600 sites were examined for physical habitat characteristics, hydromorphic attributes, and the structure of either/both the fish and aquatic invertebrate communities. The sites were located in the 15 Potomac River drainage HUCS, 7 Rappahannock River drainage HUCS, 13 York River drainage HUCS, 13 James River drainage HUCS, and 15 Miscellaneous Chesapeake Bay tributary HUCS. A total of 198 macroinvertebrate taxa were identified during the study as well as 92 species of fish. Twelve IBI metrics and seven RBP III metrics were used to characterize the fish and macroinvertebrate assemblages, respectively (Tables 2 & 3). A database containing approximately 10,000 data records (appended) was developed and used to create several multiple regression models (i.e., virtual streams) that describe statistically the expected reference conditions in first through third order streams (tidal and nontidal freshwater) of the Virginia coastal zone. These models, which will continue to be refined and validated, are used by INSTAR ver. 1.0 (<http://gaia.vcu.edu/>) to classify HUCs (modified index of biotic integrity, mIBI) and stream reaches (percentage comparable to appropriate *virtual* reference conditions) in the Virginia coastal zone on the basis of biotic integrity and overall stream ecosystem health. The INSTAR application is the primary deliverable for this project.

Also provided on this final report CD-ROM are the following report elements:

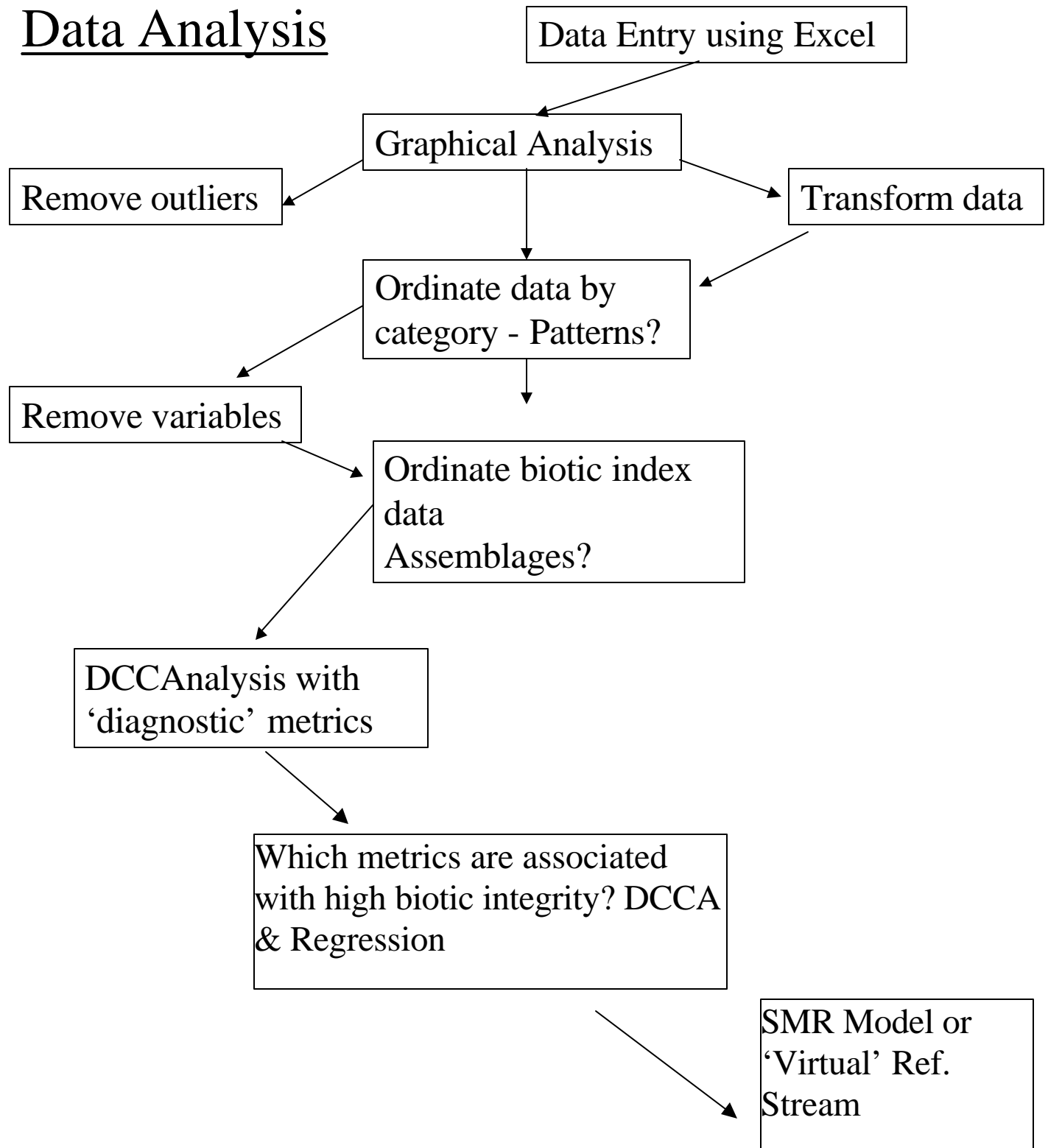
- 1) Stream database for the Virginia Coastal Zone (“Kramer”). Because all assessment scores are generated dynamically by INSTAR, we have provided only the data and collection information available as of May 14, 2004;
- 2) Metadata file for INSTAR ver. 1.0;
- 3) Fish community collection reports for the Virginia Coastal Zone
- 4) Macroinvertebrate community collection reports for the Virginia Coastal Zone
- 5) Final Report (this document) describing the project objectives, methods, and results;
- 6) Handout for INSTAR ver. 1.0 that demonstrates selected functions of the user interface;
- 7) Form “C” for task 86
- 8) Form “C” for task 88

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Figure 1. Flowchart describing multivariate analysis and model creation.



Appendix I Species codes and taxonomy for macroinvertebrates and fishes collected during pilot study.

Macroinvertebrates

Code	Order	Family	Genus	Species
AGGA	Amphipoda	Gammaridae	Gammarus	sp.
AHXX	Annelida	Hirudinea		
AOXX	Annelida	Oligochaetae		
BCCO	Bivalvia	Corbiculidae	Corbicula	fluminea
BITA			Bittacomorpha	sp.
BSMU	Bivalvia	Sphaeriidae	Musculium	sp.
BSPI	Bivalvia	Sphaeriidae	Pisidium	sp.
BSSP	Bivalvia	Sphaeriidae	Sphaerium	sp.
CDHY	Coleoptera	Dytiscidae	Hydroporus	spp.
CEAN	Coleoptera	Elmidae	Ancyronyx	variegatus
CEDU	Coleoptera	Elmidae	Dubiraphia	spp.
CEMA	Coleoptera	Elmidae	Macronychus	glabratus
CEST	Coleoptera	Elmidae	Stenelmis	spp.
CGDI	Coleoptera	Gyrinidae	Dineutes	sp.
CGGY	Coleoptera	Gyrinidae	Gyrinus	spp.
CHBE	Coleoptera	Hydrophilidae	Berosus	sp.
CHPE	Coleoptera	Halplidae	Peltodytes	sp.
CNNO	Coleoptera			
CPAN	Coleoptera	Ptilodactylidae	Anchytarsus	bicolor
DCAX	Decapoda			
DCCL	Diptera	Culicidae	Culex	sp.
DCCU	Diptera	Ceratopogonidae	Culicoides	spp.
DCPA	Diptera	Ceratopogonidae	Palpomyia	spp.
DCPR	Diptera	Ceratopogonidae	Probezzia	sp.
DCXX	Diptera	Chironomidae		
DEMX	Diptera	Empididae	Hemerodromia	sp.
DEXX	Diptera	Ephydriidae		
DSXX	Diptera	Simuliidae		
DTHE	Diptera	Tipulidae	Hexatoma	spp.
DTPI	Diptera	Tipulidae	Pilaria	spp.
DTTA	Diptera	Tabanidae	Tabanus	spp.
DTTI	Diptera	Tipulidae	Tipula	abdominalis
EBBA	Ephemeroptera	Baetidae	Baetis	spp.
EBCA	Ephemeroptera	Baetidae	Callibaetis	spp.
ECCA	Ephemeroptera	Caenidae	Caenis	sp.
EEEP	Ephemeroptera	Ephemerellidae	Ephemerella	spp.
EEEU	Ephemeroptera	Ephemerellidae	Eurylophella	temporalis
EHSI	Ephemeroptera	Heptageniidae	Stenacron	sp.
EHST	Ephemeroptera	Heptageniidae	Stenonema	modestum
ELLE	Ephemeroptera	Leptophlebiidae	Leptophlebia	sp.
ELPA	Ephemeroptera	Leptophlebiidae	Paraleptophlebia	sp.
ETTR	Ephemeroptera	Tricoridae	Tricorythodes	sp.
GAFE	Gastropoda	Ancylidae	Ferrissia	sp.
GHSO	Gastropoda	Hydrobiidae	Somatogyrus	spp.
GLLY	Gastropoda	Lymnaeidae	Lymnaea	sp.
GLPS	Gastropoda	Lymnaeidae	Pseudosuccinea	columnella
GPGY	Gastropoda	Planorbidae	Gyraulus	spp.
GPHE	Gastropoda	Planorbidae	Helisoma	sp.
GPPH	Gastropoda	Physidae	Physa	sp.
GPPL	Gastropoda	Planorbidae	Planorbula	sp.
GPPS	Gastropoda		Physella	sp.

Macroinvertebrates

Code	Order	Family	Genus	Species
GVCA	Gastropoda	Vivparidae	Campeloma	sp.
HCTR	Hemiptera	Corixidae	Trichocorixa	sp.
HESP			Hesperocorixa	sp.
HXXX	Hydracarina			
IACA	Isopoda	Asellidae	Caecidotea	sp.
LXXX	Lepidoptera			
MCNI	Megaloptera	Corydalidae	Nigronia serricornis	
MSSI	Megaloptera	Sialidae	Sialis	sp.
NXXX	Nematoda			
OABA	Odonata	Aeshnidae	Basiaeschna	sp.
OABO	Odonata	Aeshnidae	Boyeria vinosa	
OCAR	Odonata	Coenagrionidae	Argia	sp.
OCIS	Odonata	Coenagrionidae	Ischnura	sp.
OCCA	Odonata	Calopterygidae	Calopteryx	spp.
OCCO	Odonata	Cordulegastriidae	Cordulegaster	sp.
OCEN	Odonata	Coenagrionidae	Enallagma	spp.
OCEP	Odonata	Corduliidae	Epithea	sp.
OCMA	Odonata	Corduliidae	Macromia	sp.
OGLA	Odonata	Gomphidae	Lanthus	sp.
OGGO	Odonata	Gomphidae	Gomphus	spp.
OGPR	Odonata	Gomphidae	Progomphus	obscurus
OGXX	Odonata	Gomphidae		
OLCI	Odonata	Libellulidae	Celithemis	sp.
OLER	Odonata	Libellulidae	Erythemis	sp.
OLLE	Odonata	Libellulidae	Leucorminia	
OLLI	Odonata	Libellulidae	Libellula	spp.
OLNA	Odonata	Libellulidae	Nannothemis	sp.
OLPA	Odonata	Libellulidae	Pachydiplax	longipenis
OLSO	Odonata	Libellulidae	Somatochlora	spp.
PCAL	Plecoptera	Capniidae	Allocapnia	sp.
PLLE	Plecoptera	Leuctridae	Leuctra	sp.
PNPR	Plecoptera	Nemouridae	Prostoia	sp.
PPCL	Plecoptera	Perlodidae	Clioperla	clio
PPEC	Plecoptera	Perlidae	Eccoptura	xanthenes
PPIM	Plecoptera	Perlodidae	Immature	
PTTA	Plecoptera	Taeniopterygidae	Taeniopteryx	spp.
TCAN	Trichoptera		Anisocentropus	sp.
TCHE	Trichoptera		Heteroplectron	sp.
THCH	Trichoptera	Hydropsychidae	Cheumatopsyche	spp.
THHD	Trichoptera	Hydroptilidae	Hydroptila	sp.
THIM	Trichoptera	Hydropsychidae	Immature	
THOX	Trichoptera	Hydroptilidae	Oxythira	sp.
TLLE	Trichoptera	Hydroptilidae	Stactobiella	sp.
TLNE	Trichoptera	Leptoceridae	Nectopsyche	sp.
TLOE	Trichoptera	Leptoceridae	Oecetis	sp.
TLOR	Trichoptera	Leptoceridae	Orthotrichia	sp.
TLPY	Trichoptera	Limnephilidae	Pycnopsyche	sp.
TMMO	Trichoptera	Molannidae	Molanna	blenda
TPCH	Trichoptera	Philopotamidae	Chimarra	sp.
TPDU	Turbellaria	Planariidae	Dugesia	tigrina
TPLY	Trichoptera		Lype	sp.
TPNY	Trichoptera	Polycentropodidae	Nyctiophylax	sp.

.Macroinvertebrates

Code	Order	Family	Genus	Species
TPPO	Trichoptera	Polycentropodidae	Polycentropus	spp.
TPPT	Trichoptera	Phryganeidae	Ptilostomis	sp.
TPPU			Planaria	

Fishes

	Family	Genus/species	Common name
PMA	Petromyzontidae	Petromyzon marinus	Sea Lamprey
LAE	Petromyzontidae	Lampetra aepyptera	Least brook lamprey
ACA	Amiidae	Amia calva	Bowfin
ARO	Anguillidae	Anguilla rostrata	American eel
ENI	Esocidae	Esox niger	Chain pickerel
EAM	Esocidae	Esox americanus	Redfin pickerel
UPY	Umbridae	Umbra pygmaea	Eastern mudminnow
NCR	Cyprinidae	Notemigonus crysoleucas	Golden shiner
SCO	Cyprinidae	Semotilus corporalis	Fallfish
SAT	Cyprinidae	Semotilus atromaculatus	Creek chub
NLE	Cyprinidae	Nocomis leptocephalus	Bluehead chub
CYA	Cyprinidae	Cyprinella analostana	Satinfin shiner
LCO	Cyprinidae	Luxilus cornutus	Common shiner
NHU	Cyprinidae	Notropis hudsonius	Spottail shiner
NPR	Cyprinidae	Notropis procne	Swallowtail shiner
NCH	Cyprinidae	Notropis chalybaeus	Ironcolor shiner
HRE	Cyprinidae	Hybognathus regius	Eastern silvery minnow
EOB	Catostomidae	Erimyzon oblongus	Creek chubsucker
IPU	Ictaluridae	Ictalurus punctatus	Channel catfish
ANA	Ictaluridae	Ameiurus natalis	Yellow bullhead
ANE	Ictaluridae	Ameiurus nebulosus	Brown bullhead
NIN	Ictaluridae	Noturus insignis	Margined madtom
NGY	Ictaluridae	Noturus gyrinus	Tadpole madtom
ASY	Aphredoderidae	Aphredoderus sayanus	Pirate perch
GHO	Poeciliidae	Gambusia holbrooki	Eastern mosquitofish
APO	Centrarchidae	Acantharchus pomotis	Mud sunfish
CMA	Centrarchidae	Centrarchus macropterus	Flier
EBB	Centrarchidae	Enneacanthus obesus	Banded sunfish
EGL	Centrarchidae	Enneacanthus gloriosus	Bluespotted sunfish
MSA	Centrarchidae	Micropterus salmoides	Largemouth bass
LGU	Centrarchidae	Lepomis gulosus	Warmouth
LAU	Centrarchidae	Lepomis auritus	Redbreast sunfish
LMA	Centrarchidae	Lepomis macrochirus	Bluegill
LGI	Centrarchidae	Lepomis gibbosus	Pumpkinseed
PFL	Percidae	Perca flavescens	Yellow perch
PNO	Percidae	Percina notogramma	Stripeback darter
PPE	Percidae	Percina peltata	Shield darter
EOL	Percidae	Etheostoma olmstedii	Tessellated darter
EVI	Percidae	Etheostoma vitreum	Glassy darter

Appendix II

Physical habitat variables and respective symbols for ordination plots

EPIO – Epifaunal cover

PLS– Pool substrate

PLV – Pool variability

CHN – Channel alteration

SED – Sediment deposition

FLW – Channel flow status

BNKV – Bank Vegetative protection

BKST – Bank Stability

RIP – Riparian vegetative zone width

SLOPE – Rosgen slope parameter

SINUO – Sinuosity

RENT – Entrenchment ratio

RWD – Ratio stream width to depth